THE SAFETY IMPACTS OF DIFFERENTIAL SPEED LIMITS ON RURAL INTERSTATE HIGHWAYS

Nicholas J. Garber
Professor
Department of Civil Engineering, University of Virginia
P.O. Box 400742
Charlottesville, VA 22904
Telephone: (434) 924-6366
Fax: (434) 977-0832
njg@virginia.edu

John S. Miller
Senior Research Scientist
Virginia Transportation Research Council
530 Edgemont Road
Charlottesville, VA 22903
Phone: (434) 293-1999
Fax: (434) 293-1990
E-mail: John.Miller@VirginiaDOT.org

Bo Yuan
Former Graduate Student
Department of Civil Engineering, University of Virginia
P.O. Box 400742
Charlottesville, VA 22904
434-984-4208
Fax: (434) 977-0832
E-mail: courieryboo@hotmail.com

Xin Sun
Former Graduate Student
Department of Civil Engineering, University of Virginia
P.O. Box 400742
410-419-0757
Charlottesville, VA 22904
Fax: (434) 977-0832
E-mail: xs3g@cms.mail.virginia.edu

Word count: 5,076 + 5 tables + 4 figures = 7,326

ABSTRACT

To compare the safety effects of a uniform speed limit (USL) for all vehicles as opposed to a differential speed limit (DSL) for cars and heavy trucks, crash, speed, and volume data were obtained from ten states for rural interstate highways for the period 1991 to 2000. These states were divided into four policy groups based on the type of speed limit employed during the period: maintenance of a uniform limit only, maintenance of a differential limit only, a change from a uniform to a differential limit, and a change from a differential to a uniform limit. Statistical tests (analysis of variance, Tukey's test, and Dunnett's test) and the Empirical Bayes Method were used to study speed and crash rate changes in the four policy groups. This paper focuses only on the statistical tests.

No consistent safety effects of DSL as opposed to USL were observed within the scope of the study. The mean speed, 85^{th} percentile speed, median speed, and crash rates tended to increase over the ten year period, regardless of whether a DSL or USL limit was employed. When all sites within a state were analyzed, temporal differences in these variables were often not significant; however, in several cases, significance was observed if one then excluded sites with unusually high or low traffic volumes from the data set. Further examination suggests that while these data do not show a distinction between DSL and USL safety impacts, the relationship between crashes and traffic volume cannot be generalized but instead varies by site within a single state.

INTRODUCTION

The Surface Transportation and Uniform Relocation Assistance (STURA) Act, enacted on April 2, 1987, permitted individual states to raise rural interstate speed limits from the previously mandated national speed limit of 89 km/h (55 mi/h) to 105 km/h (65 mi/h) on rural interstate highways. Of those that changed their speed limits, some states raised the limits for passenger cars but not trucks, and other states raised the limits for both passenger cars and trucks. The former category, with different speed limits for cars and trucks, is known as Differential Speed Limits (DSL), while the latter category, the same speed limits for cars and trucks, is known as uniform speed limits (USL). The 1995 repeal of the national maximum speed limit further gave states further flexibility in setting their limits, such that by 2002 several states had at one point or another experimented with both DSL and USL.

Proponents of DSL note that heavy trucks require a larger stopping distance and stopping time than passenger cars. Thus, a lower speed for trucks would reduce the crash risk that would otherwise be associated with these larger vehicles traveling at high speeds. Proponents of USL contend that different limits could increase speed variance, resulting in more conflicts between trucks and other types of vehicles, especially certain types of crashes, such as rear-end and side swipe collisions. Advocates of a uniform limit suggested that the higher driver position in a truck provides a greater sight distance than would be the case for a passenger car, giving truck drivers more time to stop.

Studies conducted during the early 1990s to compare the safety impacts of USL and DSL were constrained because of the limited data available at that time. Most such studies compared effects at different physical sites, such as Interstate 64 in the western portion of Virginia and the adjacent section of Interstate 64 in the eastern portion of West Virginia, where, in 1990 West Virginia had a uniform limit and Virginia had a differential limit. With more than a decade having elapsed since the passage of STURA, however, the Federal Highway Administration (FHWA) requested that a longitudinal study be conducted, focusing especially on states that had changed their limits from USL to DSL or vice-versa.

PURPOSE AND SCOPE

The purpose of this study is to compare the safety impacts of DSL and USL on rural interstate highways. Thus the study's objectives are twofold:

1. To compare the effect of DSL and USL on crashes.
2. To compare the effect of DSL and USL on vehicle speeds.

The scope of this study is limited to crash and speed data available in the U.S. on select rural interstate highways between the period 1990 and 2000.

LITERATURE REVIEW

Previous authors had focused on three main indicators of safety: speed, speed variance, and crashes themselves, and the results have been inconsistent.

Impact of DSL on Mean Speed

In 1990, Freedman and Williams analyzed speed data collected at 54 sites in 11 Northeastern states to determine the effect of DSL on mean and 85th percentile speeds (*1*). Six states had retained a uniform limit of 89 km/h (55 mi/h), three had raised speed limits for all vehicles to a uniform value of 105 km/h (65 mi/h), and two states employed a differential limit for cars and trucks respectively of 105/89 km/h (65/55 mi/h). The results showed that for *passenger cars*, the mean speed and 85th percentile speed for the two DSL states were not significantly different from the states with a uniform limit of 105 km/h (65 mi/h). Further, the mean and 85th percentile *truck* speeds in DSL states were close to those of the USL states. Similar results were obtained when comparing the percentage of vehicles complying with the speed limit. Harkey and Mera also found there to be no significant difference between passenger car and truck mean speeds when comparing DSL and USL (*2*). Garber and Gadiraju, however, did find a significant difference between truck mean speeds under DSL and USL, as well as an increase in passenger cars' mean speed when the speed limits for those vehicles were raised (*3*).

Impact of DSL on Speed Variance

Garber and Gadiraju also found that speed variance for all types of vehicles were significantly greater at DSL sites than at non-DSL sites (*3*). The implication of increased variance is increased interactions between vehicles and thus a potentially larger possibility of some types of crashes. While they found differences in truck speed variance in ten of thirteen pairwise comparisons between a USL site and DSL site, Harkey and Mera found no significant differences were between car speed variances at the DSL and USL sites (*2*). Furthermore, they found no difference between the speed distributions for both cars and trucks for the 105/97 km/h (65/60 mi/h) and 105/105 km/h (65/65 mi/h) speed limits.

Impact of DSL on Crashes

Harkey and Mera also looked at crash results from 26 sites in eleven states (*2*). Those authors found that a higher proportion of car-into-truck and truck-into-car crashes occurred in USL states than in DSL states, except for rear end crashes where more car-into-truck collisions happened in the DSL group. In contrast, Garber and Gadiraju, who had compared sites in three DSL states (California, Michigan and Virginia) against two USL states (Maryland and West Virginia) found no statistically significant differences between crash rates when stratifying by collision type and crash severity (*3*). Council, Duncan and Khattack in 1998 found that for rear end collisions between cars and trucks, a high speed differential increases the severity of the crash (*4*). A simulation study by Garber reported a potential for an increase in crash rates for facilities using DSL, especially in the case of high vehicle volumes and truck percentages (*5*).

Further, a 1991 study found no evidence indicating that the increase of the speed limit to 105 km/h (65 mi/h) for trucks at the test sites resulted in a significant increase in fatal, injury and overall accident rates (*6*). In that study, comparisons of crash rates in the adjacent states of Virginia (DSL) and West Virginia (USL) showed relatively more rear-end crashes in Virginia, suggesting that DSL might have a negative impact on safety.

Lending credence to the use of speed variance as a surrogate for crashes, Garber and Gadiraju found that crash rates increased with increasing speed variance for all classes of roads (*7*). A 1974 study by Hall and Dickinson had showed that speed differences contributed to crashes, primarily rear end and lane change collisions (*8*). The existence of a posted DSL, however, was not found to be related to the occurrence of truck crashes. The study also noted that lower rates of truck crashes could be expected with higher speed limits and hence the study recommended an increase of truck speed limits from to 105 km/h (65 mi/h) for highways carrying a higher truck percentage. Finally, an evaluation conducted by the Idaho Department of Transportation found that a change from USL to DSL did not increase crashes (*9*).

METHODOLOGY

Analytical Steps

Four basic steps comprised the methods used to compare the safety impacts of DSL and USL.

1. *Crash and speed data were synthesized from 17 different states* that had been recommended by FHWA, other researchers, or representatives who indicated the states had changed their speed limits at least once during the 1990s from USL to DSL or vice versa. Of these 17 states, ten were suitable for analysis, after checking the data sets for completeness, accuracy, and usability.

2. *Average daily traffic (ADT) was used to filter the speed and crash data such that sites with relatively high or low ADTs were removed from the analysis.* The rationale for this ADT-based filtering is that ADT may influence both the speed distribution and the crash risk, thus with its removal one should be more able to identify effects on speeds and crashes that are due to changes in the speed limit.

3. *Conventional statistical approaches, such as the analysis of variance (ANOVA), were used to analyze speed monitoring data from these states.* To the extent possible with available data, annual changes in five speed variables (mean speed, speed variance, 85th percentile speed, median speed, and noncompliance rates) were studied. Two types of comparisons were undertaken:

    - *"Before and After" comparisons* within individual states if the state had changed from USL to DSL or vice versa. (For those states that never changed their policy, the data were categorized into two virtual groups, 1990 - 1995 and 1996 – 2000, in order to determine whether significant changes occurred over time even without a policy shift between USL and DSL.)

- *Year by year comparisons.* When ANOVA detected a significant difference at the 5% confidence level was detected for these yearly changes, then three additional statistical tests were employed. Levene's test served as a screening procedure to determine if the groups had equal variances. If so, then Tukey's test was used to determine whether the differences were significant, while Dunnett's test was used for samples with unequal variances, since the former assumes equal variances and the latter does not *(10,11,12)*

4. Similar approaches were used to compare crash rate data. Six types of crash rates were studied: total, fatal only, rear end only, total truck involved, fatal truck involved, and truck involved rear end. The crash rate was computed as shown in equation (1) below, where the annual crash frequency was simply the annual number of crashes, the ADT was the average daily traffic *(13)*.

$$Crash\ rate = \frac{(100{,}000{,}000)(Annual\ Crash\ Frequency)}{(365)(ADT)(Section\ Length)} \qquad (1)$$

Overview of Available Data

Table 1 shows that the states which provided data that were used in this study may be divided into four *policy groups* based on their speed limits during the 1990s:

1. States that maintained a uniform limit for cars and trucks
2. States that maintained a differential limit for cars and trucks
3. States that changed from a uniform to a differential limit
4. States that changed from a differential to a uniform limit

RESULTS, DISCUSSION, AND LIMITATIONS

The results of the analysis are presented across two key areas: vehicle speeds as collected from speed monitoring data and evaluated using conventional statistical approaches and crash rates that were evaluated using conventional statistical approaches.

Vehicle Speeds

The five types of speed data (mean speeds, speed variance, 85th percentile speeds, median speeds, and noncompliance rates) were analyzed for all states where such speed monitoring data were readily available.

Mean Speeds: An Example of How the Data May be Assessed

Figure 1 illustrates the trend in mean speeds among five states from which speed data were analyzed. Two observations that arise from examination of Figure 1 are that except for Virginia, speeds appear to be increasing over time (whether or not the differences are practically or statistically significant), and unfortunately one cannot always obtain data for all time periods.

Tables 2 and 3 illustrate the two types of analyses that were conducted for all speed and crash data: a before-after analysis, to determine whether the speeds from the before period were significantly different from the after period at the 95% confidence level, and a year-by-year analysis, to tell whether individual years showed a significant difference. The reason for the year-by-year approach is that it helps one interpret the before/after results: for example, if the annual results show no significant difference except when one compares years from the before period to years from the after period, then the evidence is strong that the difference between the before and after years is significant. For this paper, p values of 0.05 or lower were considered significant.

Note that Table 2 gives two sets of results for Idaho since Table 1 shows its speed limits were changed twice: first a raising of its uniform limits, and second a lowering of truck speeds only. Note also that in Table 3, since the Levene test had shown the variances to be significantly different, Dunnett's test was used to compare annual mean speeds as Dunnett's test does not require comparison groups to have similar variances.

Examination of the statistics in Table 2 shows that the mean speed of Iowa, which maintained a uniform limit, increased by 3.6 km/h (2.2 mi/h) which was significant. The mean speed change for Idaho, which maintained a uniform speed limit but increased that limit by 16 km/h (10mi/h) for all vehicles, was also significant with an increase of 9.2 km/h (5.7 mi/h). In the two states of Illinois and Indiana that maintained DSL, their mean speed increased by 1.2 km/h (0.8 mi/h) and 3 km/h (1.9 mi/h), respectively, which were not significant. Also, Idaho's second change, which was a shift from a uniform to a differential limit, resulted in a slight decrease in the mean speed of 0.18 km/h (0.11 mi/h) but this decrease was not significant. The mean speed in Virginia, which changed from differential to uniform by increasing the speed limit for trucks by 16 km/h (10 mi/h), decreased by 1.15 km/h (0.71 mi/h), which was insignificant. It should also be noted that in examining the results of the year to year analysis shown in Table 3, the mean speed in Iowa for 1999, after the change from uniform to differential, was significantly higher than that for 1996, before the change, and that for 2001 was significantly lower for 1995.

Graphical Overview of Changes in Speed Variance, 85th Percentile Speed, Median Speed, and Noncompliance Rates

Figures 1, 2, and 3 give a pictorial understanding of how speeds changed from 1991 to 2000 for the states where data were available. These figures facilitated the observations of three general phenomena. *First*, there appears to be some correlation among the speed variables where data are available. For example, the mean and median speeds for Virginia are similar to one another, and the same can be said for Indiana. Likewise, the mean speeds and 85th percentile speeds for Idaho show similar trends. Although this is not surprising, it is not something to take for granted, since it has been reported elsewhere that differences can sometimes be observed in the 85th percentile speed even though no differences are observed in mean speeds (*14*). *Second*, there is not a clear difference in behavior between uniform and differential states. For example, Iowa (always uniform limit) and Illinois (always differential limit) show similar upside down

"V" curves with respect to speed variance. Similarly, most states tended to show an overall increase in mean speeds. Virginia (the one state that went from differential to uniform) did show a decrease in mean speeds, however, Table 2 reminds us that this difference was not significant. (Further, Table 4 will show that decreases in Virginia for the 85th percentile and median speeds were also not significant). *Third*, Figure 3 suggests, but does not prove, that there is a correlation between speed variance and noncompliance rates. The small data available do not justify firm conclusions, but do suggest a relationship worthy of further study.

Statistical Results of Changes in Speed Variance, 85th Percentile Speed, Median Speed, and Noncompliance Rates

Table 4 highlights the results of the statistical analysis and suggests that while increasing speeds were observed in most cases, these were not usually significant. (Powerful exceptions are Idaho and Iowa, which definitely do show a significant increase in speeds; it should be noted, however, that Iowa had a small number of sites.) The fact that no state showed a significant decrease in speeds and that states from all four policy groups showed either a significant or insignificant increase lends weight to the idea that changes in speed as a result of a differential or uniform speed limit were not supported by this study.

As an example of the influence of other factors, consider the noncompliance rates. In Virginia, these data were only available for three years: 1991, 2000, and 2001, with the percentage of drivers exceeding the speed limit being 77%, 55.2, and 50% respectively. Differences between the before DSL period (1991) and the after DSL period (2000 and 2001) were significant, whereas differences between 2000 and 2001 were not significant. Statistically speaking, therefore, a strong case can be made that this state's results suggest that elimination of DSL was correlated with a lowering of the noncompliance rate in this one particular state. Given the sparse data available from Virginia, which in turn is more than that available from other states, however, this inference is tenuous at best given the small data points shown in Figure 3.

Discussion of Speed Impacts

Several inferences are apparent from examining these speed data.

- Significant increases in mean speed for Idaho and Iowa were observed over the study period. The other states tended to show insignificant increases. This trend suggests that the mean speed tended to increase over the 1990s regardless of whether the speed limit was uniform or differential. The 85th percentile speeds and median speeds showed a comparable upward trend, although fewer data were available for those two variables.

- Idaho's first speed limit change, from a uniform limit of 105 km/h (65 mi/h) to a uniform limit of 121 km/h (75 mi/h), resulted in a significant increase in both the mean speed and the 85th percentile speed.

- Idaho's second speed limit change, from a uniform limit of 121 km/h (75 mi/h) to a differential limit of 121/105 km/h (75/65 mi/h) did not significantly change either the mean speed or the 85th percentile speed, although these did decrease slightly.

- In Illinois, where no speed limit changes were implemented, the noncompliance rate increased steadily. Given the increasing mean speed of Illinois, this could be due to drivers desiring to travel at a higher speed.

Crash Rates

Table 1 showed that there were six states (Arizona, Missouri, North Carolina, Arkansas, Idaho and Virginia) from which crash rate data could be obtained. Six types of crash rates (total crash rate, fatal crash rate, rear end crash rate, total truck-involved crash rate, truck-involved fatal crash rate, and truck-involved rear end crash rate) were evaluated. As was done with the speed data, both a before-after comparison and a year-pair comparison were performed. (Again, for those states that never changed their policy, the data were categorized into two virtual groups, 1990 - 1995 and 1996 - 2000.) Unlike the speed analysis, however, these statistical tests were applied twice: once on all the segments, and once on only those segments that remained after segments with particularly high or low ADTs had been filtered.

Figure 4 graphically compares the total crash rate in the six states for all sites against that crash rate with the high and low ADT sites removed, while Table 5 indicates which changes were significant. Of the three states that maintained a uniform limit, one (North Carolina) showed a significant increase in the total crash rate whereas Arizona and Missouri only showed insignificant increases.) Once sites with high and low ADTs were removed, however, then Arizona's increase in crash rates also became significant. None of the other states, which all had either changed from differential to uniform or from uniform to differential, showed a significant change in the total crash rate.

Table 5 shows the before versus after period change in the six types of crash rates of the various six states, with the p values from the ANOVA test given in parentheses. In examining Table 5, it is apparent that there were 27 cases where both an ADT and a crash rate were available. Without ADT filtering, there was a significant difference between the before and after period in three of those 27 cases; whereas with ADT filtering there was a significant difference in nine out of those 27 cases. Thus clearly the ADT filtering in this case had the effect of reducing within-group variation in order to make differences between the before and after groups more apparent.

Table 5 shows that as was the case with the speed analysis, there is no consistent trend in crash rates matching the change in speed limits. Tellingly, Virginia and Arkansas – two states that were diametrically opposed in terms of their policies (Arkansas changed to differential and Virginia changed from differential) both showed a statistically significant increase in total truck-involved crashes once sites with high and low ADTs were filtered out of the analysis.

On the basis of the limited data available, one might be tempted to state that there is evidence that the change to a uniform limit (as was done in Virginia) resulted in an increase in the number of rear end crashes since the number of rear end crashes increased in Virginia. This viewpoint, however, is tempered by two observations: first, such an increase is significant only when removing high and low ADT sites, and second, there is no corresponding decrease in the states that shifted from uniform to differential. In fact, the states that made the shift from uniform to differential (Idaho and Arkansas) saw an increase (albeit insignificant) in the number of rear end crashes. It should also be noted that Virginia observed a reduction in the fatal crash rates after the change from DSL to uniform, while Idaho observed an increase in the fatal crash rate after changing from USL to DSL, although both of these changes were insignificant.

The most striking feature of Table 5 is that despite all four combinations of speed limit policies (maintaining a uniform limit, maintaining a differential limit, changing from uniform to differential or vice-versa), not a single state saw a significant decrease in any of the various crash rate categories, regardless of whether ADT filtering was used. Crash rates either did not change significantly or significantly increased.

Limitations

Caveats to This Study

Five limitations of this study are noted. *First*, the sample size varied by state: for example, one is less certain of the Missouri results (based on three sites) being representative of Missouri than one is of the Arizona results (based on 556 sites) being representative of Arizona. *Second*, the selected sites may be an unbiased sample; however, the investigators cannot control site selection; their randomness is a function of how individual state set up their individual speed monitoring programs. *Third*, the durations used in this study are relatively short: certainly three years is normal for a before/after study, but some of these states, notably Idaho, only had a speed limit in effect for one to two years. *Fourth*, the rural interstates were analyzed at an annual level of detail, without stratification by time period or season. Fortunately, since congestion is usually lower for rural interstates, this annual approach should not have been as significant a problem as it would have been for urban interstates. *Fifth*, the sample size used in the statistical tests associated with the speed analysis was defined as the number of speed monitoring sites rather than the number of vehicles, in part because the latter data element was not available for some states. In cases where the data were available, usage of that data element would have lead to the states of Virginia and Idaho showing significant (rather than insignificant) differences in mean speeds, which would still lead to the same conclusions shown below.

Details Not Presented in this Paper

Although not presented here, the investigators examined speed changes and crash changes on specific Interstates for the states of Idaho and Virginia, respectively, owing to the concern that perhaps a state by state approach was too aggregate a level of analysis. The findings from these study of individual interstates in these two states did not, however, change the overall findings of this study. That analysis did show, however, that between-interstate variation adds quite a bit of noise to any attempt to study statewide temporal trends and thus a promising endeavor for future work is to reapply this analysis at the interstate level. The investigators also applied the Empirical Bayes approach to evaluate crash frequency changes without presuming a constant relationship between crashes and traffic volume, and the results of that approach will be forthcoming in a separate publication.

CONCLUSIONS

1. *Speed characteristics were generally unaffected by a differential versus uniform speed limit policy.* Except in Virginia, mean, 85th percentile, and median speeds tended to increase over the 1990s regardless of whether the state maintained a uniform limit, maintained a differential limit, or changed from one to the other. In some cases the difference was significant, in other cases the difference was not significant.

2. *Crash rates*, when compared using conventional statistical methods, did not show an obvious relationship to the type of speed limit chosen. When states were stratified into four policy groups (uniform, differential, shift from uniform to differential, and vice-versa), the changes in crash rates and crash rate types did not all correspond to one group.

3. *Measurable variation within speeds and crash rates by year and by state may confound any statistical tests employed.* The performance of Illinois annual speed variances as shown in Figure 3 is indicative of the noise associated with random variation, where the annual speed variance has an insignificant but observable upwards and downwards trend despite the fact that Illinois made no policy changes to its speed limits.

4. *Removal of sites with high and low ADT made it easier to detect significant differences between before and after periods, suggesting that ADT does influence crash trends.* As was observed in Table 5, this ADT filtering did not change the finding that there is no consistent relationship between speed limit type and crash rate; further, the effect of ADT on crash rate is not clear. This study simply suggests that, through different mechanisms not yet proven by the investigators, change in ADT may have disproportionate changes in crash rates.

ACKNOWLEDGEMENTS

The investigators gratefully acknowledge the many persons who provided data, insights, assistance, and other contributions to this effort. Any person who has worked with state crash and speed data will recognize that obtaining these data, especially data from as far back as a dozen years ago, is no small undertaking. Thus assistance from K. Bonds (Arkansas), J. Williams (Arizona), C. Haack and J. Benton (California), N. Brizzi (Idaho), L. Rust (Indiana), W. Baldwin, G. Groat, M. Pawlovich, and T. Welch (Iowa), J. Schaefer (Missouri), P. Jomini and V. Gonzales (Montana), S. Cosper and A. Wyatt (North Carolina), L. Evans, D. Gardner, J. Hausman, and S. Shokouhi (Ohio), S. Reed (Oregon), R. Collins and M. Moore (Texas), B. Siddiqui (Utah), T. Rickman and K. Tanner (Washington), J. Legg, R. Lewis, and R. Russell (West Virginia) proved essential to this study. The team also could not have accomplished this work without the assistance of L. Woodson (Virginia) whose expertise for data reduction was needed. Finally, this research was sponsored by the Federal Highway Administration and

managed by Davey Warren of FHWA. Inclusion of these names, states, and agencies does not imply agreement with the results of this study.

REFERENCES

1. Freedman, M. and A.F. Williams. "Speeds Associated with 55 mph and 65 mph Speed Limits for Cars and Trucks: Do they Affect Vehicle Speeds?" *Transportation Research Record 1318,* TRB, National Research Council, Washington, D.C., 1991.

2. Harkey, David L. and R. Mera. *Safety Impacts of Different Speed Limits on Cars and Trucks,* US Department of Transportation, Federal Highway Administration, Publication No. FHWA-RD-93-161, Washington, D.C., May 1994.

3. Garber, N.J. and R. Gadiraju. *Impact of Differential Speed Limits on Highway Speeds and Accidents,* AAA Foundation for Traffic Studies, Washington, D.C. February 1991.

4. Council, F. M., Duncan, C.S., and A.J. Khattack. "Applying the Ordered Probit Model to Injury Severity in Truck-Passenger Car Rear-End Collisions," *Transportation Research Record 1635,* TRB, National Research Council, Washington, D.C., 1998.

5. Garber N.J. and R. Gadiraju. *Effect of Truck Strategies on Traffic Flow and Safety on Multilane Highways,* AAA foundation for Traffic Safety, July 1989.

6. Garber N.J. and R. Gadiraju. *Impact of Differential Speed Limits on Highway Speeds and Accidents*, Dept. of Civil Engineering, University of Virginia, Charlottesville, VA, 1991, pp13.

7. Garber N.J., and R. Gadiraju. *Speed Variance and its Influence on Accidents*, AAA Foundation for Traffic Safety, July, 1988.

8. J.W. hall and L. V. Dickinson. *An Operational Evaluation of Truck Speeds on Interstate Highways*, Department of Civil Engineering, University of Maryland, February, 1974.

9. Idaho Transportation Department Planning Division. *Evaluation of the Impacts of Reducing Truck Speeds on Interstate Highways in Idaho, -Phase III, Final Report* Dec.,2000, National Institute fro Advanced Transportation Technology University of Idaho.

10. K. A. Brownlee. *Statistical Theory and Methodology in Science and Engineering*, John Wiley & Sons, Inc. 1960.

11. SPSS. *Post-Hoc Test introductions by SPSS; Appendix 10: Post Hoc Tests.* Viewed at www.spss.com/tech/stat/algorithms/11.0/app10_post_hoc_tests.pdf on April 16, 2002.

12. Sahai, H. and M.I. Ageel. *The Analysis of Variance, Fixed, Random and Mixed Models,* Birkhauser, 2000.

13. Garber, N.J. and L.A. Hoel. *Traffic and Highway Engineering*, PWS Publishing, 1996.

14. McShane, W.R. and R. P. Roess. *Traffic Engineering*, Prentice Hall, Englewood Cliffs, New Jersey, 1990.

List of Figures

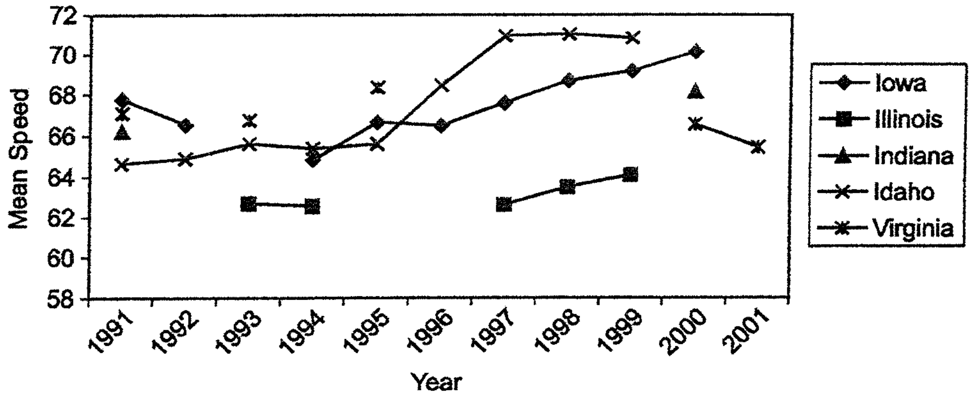

Figure 1. Mean Speed for All Vehicles

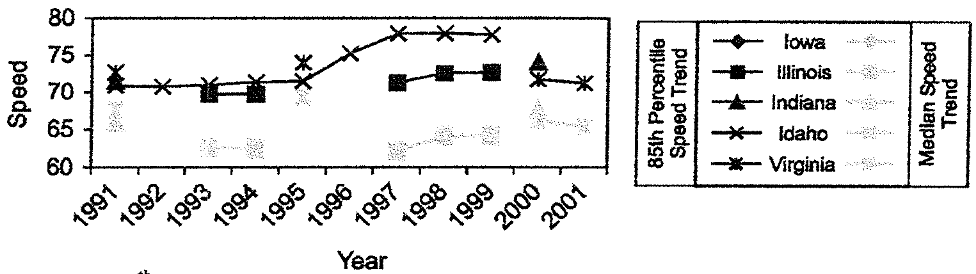

Figure 2. 85th Percentile Speeds and Median Speeds
Note that speed limits changed in Idaho (1996, 1998), Arkansas (1996), and Virginia (1994)

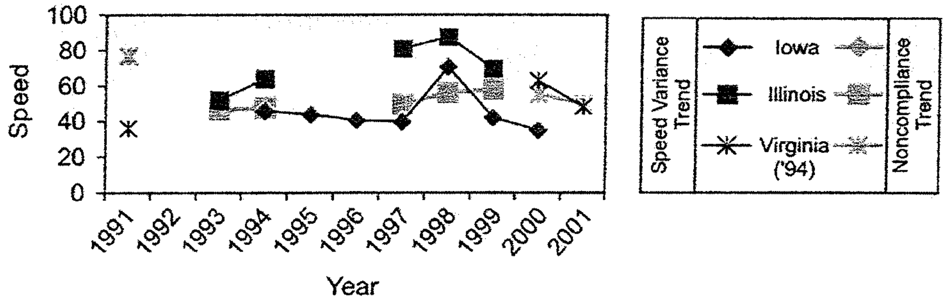

Figure 3. Speed Variance and Noncompliance Rates (years of speed limit changes in parentheses)
(Note that vertical axis gives speeds for *speed variance* and percentage of violators for *noncompliance*)

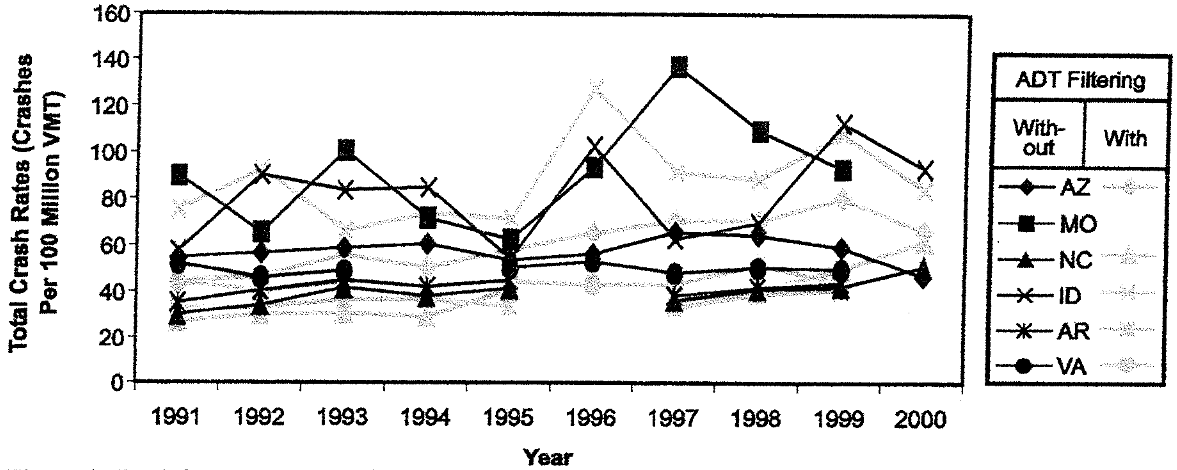

Figure 4. Total Crash Rates: All Sites Versus Sites that Were Filtered by ADT
Note that speed limits changed in Idaho (1996, 1998), Arkansas (1996), and Virginia (1994)

List of Tables

Table 1. Overview of Data Availability from the Various States

Rural Interstate Speed Limits: 1991 – 2000		Crash Data	Speed Data
Policy Group 1: Maintained a Uniform Speed Limit			
Arizona	121 km/h (75 mi/h)	Y	N
Iowa	105 km/h (65 mi/h)	N	Y
Missouri	89 km/h (55 mi/h) before 1996 113 km/h (70 mi/h) after 1996	Y	N
North Carolina	105 km/h (65 mi/h) before 1996 113 km/h (70 mi/h) after 1996	Y	N
Policy Group 2: Maintained a Differential Speed Limit (passenger cars/trucks)			
Illinois	113/105 km/h (70/65 mi/h)	N	Y
Indiana	105/97 km/h (65/60 mi/h)	N	Y
Washington	No Speed Limits	N	N
Policy Group 3: Changed from Uniform to Differential Speed Limit (passenger cars/trucks)			
Arkansas	From: 105 km/h (65 mi/h) To: 113/105 km/h (70/65 mi/h) 1996	Y	N
Idaho	From: 105 km/h (65 mi/h) To: 121 km/h (75 mi/h) 1996 To: 121/105 km/h (75/65 mi/h), 1998	Y	Y
Policy Group 4: Changed from Differential to Uniform Speed Limit (passenger cars/trucks			
Virginia	From: 105/89 km/h (65/55 mi/h) To: 105 km/h (65 mi/h), 1994	Y	Y

Table 2. Before/After Mean Speed Comparisons from the ANOVA test: *p* Values

Policy Group	State	Before-After p
Group 1 (uniform limit)	Iowa	0.000*(+)
Group 2 (differential limit)	Illinois	0.626(+)
	Indiana	0.537(+)
Group 3 (uniform to differential)	Idaho	0.000* (+) (uniform to uniform) 0.790(-) (uniform to differential)
Group 4 (differential to uniform)	Virginia	0.318(-)

*designates a significant difference at the 0.05 level

Table 3. Annual Mean Speed Comparisons

State	*p* values for tests of significant differences in the *variances* (based on Levene's test)	Years where the *means* are significantly different at the 0.05 level. (based on Dunnett's Test)
Iowa	.000*	1995<2000, 1996<2000, 1997<2000
Idaho	.000*	1991<1996, 1992<1996, 1993<1996, 1994<1996, 1995<1996, 1996<1997, 1996<1998, 1996<1999
Virginia	.004*	1995>2001

*designates a significant difference at the 0.05 level

Table 4. Longitudinal Comparison of Speed Variables Within the States

Policy Group	State	Variable	*p* value	Effect from Before to After Period	Significant at the 5% confidence level?
1: Uniform Limit	Iowa	Mean Speed	0.000	Increase	Y
		Speed Variance	0.878	Increase	N
		85th Percentile Speed			
		Median Speed			
		Noncompliance			
2: Differential Limit	Illinois	Mean Speed	0.626	Increase	N
		Speed Variance	0.250	Increase	N
		85th Percentile Speed	0.171	Increase	N
		Median Speed	0.535	Increase	N
		Noncompliance	0.350	Increase	N
	Indiana	Mean Speed	0.537	Increase	N
		Speed Variance			
		85th Percentile Speed	0.338	Increase	N
		Median Speed	0.608	Increase	N
		Noncompliance			
3: Uniform to Differential	Idaho	Mean Speed	0.000, 0.790	Increase, Decrease	Y, N
		Speed Variance			
		85th Percentile Speed	0.000, 0.563	Increase, Decrease	Y, N
		Median Speed			
		Noncompliance			
4: Differential to Uniform	Virginia	Mean Speed	0.318	Decrease	N
		Speed Variance	0.136	Increase	N
		85th Percentile Speed	0.356	Decrease	N
		Median Speed	0.209	Decrease	N
		Noncompliance	0.000	Decrease	Y

Table 5. Statistical Tests for the Significance in Crash Rates

Policy Group	State	Type of Crash Rate	Before-After Analysis Result			
			All Sites		ADT Filtered Sites	
			Difference	Significance (p)	Difference	Significance (p)
Group 1: maintained a uniform limit	Arizona	Total	+	N (0.583)	+	Y (0.000)
		Fatal	+	N (0.140)	+	N (0.075)
		Rear end	+	N (0.052)	+	Y (0.000)
		Total truck involved	+	N (0.949)	+	Y (0.016)
		Truck-involved fatal	+	N (0.134)	+	Y (0.044)
		Truck-involved rear end	+	N (0.406)	+	N (0.085
	Missouri	Total	+	N (0.218)		
		Fatal	-	N (0.286)		
		Rear end	+	N (0.256)		
		Total truck involved	+	Y (0.001)		
		Truck-involved fatal				
		Truck-involved rear end				
	North Carolina	Total	+	Y (0.007)	+	Y (0.001)
		Fatal	+	N (0.100)	-	N (0.999)
		Rear end	+	Y (0.035)	+	Y (0.040)
		Total truck involved	+	N (0.504)	+	N (0.395)
		Truck-involved fatal	-	N (0.525)	-	N (0.447)
		Truck-involved rear end	+	N (0.366)	+	N (0.202)
Group 3: Changed from Uniform to Differential Limit	Arkansas	Total	-	N (0.935)	+	N (0.325)
		Fatal	+	N (0.495)	+	N (0.718)
		Rear end	+	N (0.258)	+	N (0.066)
		Total truck involved	+	N (0.250)	+	Y (0.015)
		Truck-involved fatal				
		Truck-involved rear end				
	Idaho	Total	-, +	N, N (0.539,0.153)	+, +	N, N (0.474, 0.851)
		Fatal	-, +	N, N (0.336,0.192)	-, +	N, N (0.581, 0.223)
		Rear end	-, +	N, N (0.539, 0.327)	-, +	N, N (0.281,0.622)
		Total truck involved	-, +	N, N (0.473,0.139)	-, +	N, N (0.605,0.294)
		Truck-involved fatal	-, 0	N, N (0.656,1.000)	-, 0	N, N (0.658,1.000)
		Truck-involved rear end	-, +	N, N (0.820,0.370)	-, +	N, N (0.994, 0.477)
Group 4: Changed from Differential to Uniform	Virginia	Total	+	N (0.425)	+	N (0.287)
		Fatal	-	N (0.270)	-	N (0.704)
		Rear end	+	N (0.119)	+	Y (0.026)
		Total truck involved	+	Y (0.000)	+	Y (0.002)
		Truck-involved fatal	+	N (0.665)	+	N (0.894)
		Truck-involved rear end				

Note that the number of truck involved fatal crashes was zero in Idaho which is why "1.000" is shown in that cell.

Paper revised from original submittal.